



R.C.A. INSTITUTES

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Technical Lesson 21

ELECTROMAGNETIC WAVES

Electromagnetic waves constitute a form of energy in the transmission of Radio and, in a way, possess some of the general characteristics found in the transmission of radiant heat, sound and light waves. For example, when a violin is bowed the strings are set into vibration creating sound waves. The flame of a candle sets up vibrations creating waves which, on passing the eye, produce the sensation of light.

In Radio transmission a disturbance is created at the source which moves away through space in the form of electromagnetic waves. Wherever wave motion is created it always represents a form of energy which is transmitted through a medium having the ability to conduct the particular wave in question.

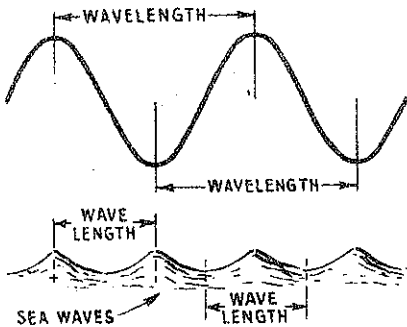


Figure 1

Sound waves are transmitted by a condensation and rarefaction of air particles.

Whenever wave motion is present it is always caused by a vibration of some form at its source. To produce a radio wave, then, we must set up electrical vibrations at the transmitting source.

From the study of sound you remember we found that a sound wave was created by vibrations and that this wave had frequency, velocity, and length (wave length). The electromagnetic wave also has these same properties and they are all definitely related to one another. The frequency is expressed, you will recall, in cycles. When the frequency of electrical current reaches 1000 cycles, it may be then called one kilocycle, (kilo meaning one thousand). In radio transmission the frequency is spoken of in terms of kilocycles because of the extremely high frequencies employed for broadcasting work, ranging from 550,000 to 1,500,000 cycles per second. Since 1000 cycles equal one kilocycle we can use the more convenient term to work with. For example, dividing 550,000 cycles by 1000 will give us 550 kilocycles and in the same manner 1,500,000 cycles will be equal to 1500 kilocycles. The frequency of the broadcast range varies from 550 K.C. (kilocycles) to 1500 K.C. (kilocycles).

As explained in the previous lesson a wave has two motions which are opposite, - one the crest, and the other the trough. Wave length is determined by measuring from a point on one wave to a similar point

on the next wave as, for example, from crest to crest or trough to trough. This is graphically shown in Figure 1.

The velocity of sound waves is about 1,100 feet per second. Electromagnetic, or radio waves, however, travel at the terrific speed of nearly 300,000,000 meters per second (one meter is equal to 39.37 inches, or 3.280 feet) which is approximately 186,300 miles per second. The relation between these properties is definite and, considering the velocity a definite value, the frequency and wave length can be varied.

This brings us again to the basic formula given in the study of sound. Velocity is equal to the frequency times the wave length, $V = f \times \lambda$. Frequency equals velocity divided by the wave length, $F = V \div \lambda$. The wave length is equal to the velocity divided by the frequency, $\lambda = V \div F$. λ (lambda) is the symbol for wave length.

When the wave rises and falls a great many times per second it is said to have high frequency, that is, when the frequency is high the wave length is short. Let us use our formula to prove this, choosing an arbitrary frequency as, for example, 600,000 cycles and, with a velocity of 300,000,000 meters.

$$\lambda = \frac{V}{F}$$

$$\lambda = \frac{300,000,000}{600,000}$$

$$\text{or, } \lambda = 500 \text{ meters}$$

Suppose our frequency is increased to 7,500,000 cycles per second, then

$$\lambda = \frac{V}{F}$$

$$\lambda = \frac{300,000,000}{7,500,000}$$

$$\text{or, } \lambda = 40 \text{ meters}$$

Now decrease the frequency to 20,000 cycles per second,

$$\lambda = \frac{V}{F}$$

$$\lambda = \frac{300,000,000}{20,000}$$

$$\text{or, } \lambda = 15,000 \text{ meters.}$$

Thus it is seen that, as the frequency is increased, the wave length becomes shorter and when decreased the wave length becomes longer, as shown by the diagram Figure 2. The relation existing between frequency, velocity, and wave length is always the same, as shown by the foregoing formulae.

Radio waves are classified as continuous and damped. A continuous wave, abbreviated (CW), is one whose oscillations producing the wave will be of constant amplitude, providing the electrical energy producing the wave is kept at a constant value. Damped waves are those set up by energy which is supplied by the transmitter at intervals; such waves gradually die out according to a logarithmic law which will be considered later under transmitters.

If you set a violin string into vibration by one short quickly executed stroke of the bow the vibrations will produce a sound wave, the form of

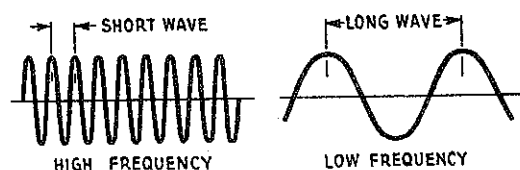


Figure 2

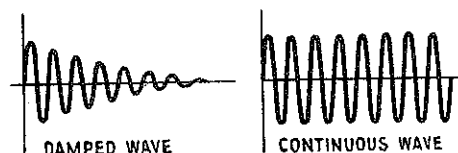


Figure 3

which will be damped, that is, the vibration of the string will be of maximum amplitude at first and the resulting wave motion will produce a loud sound which will gradually die away. A damped wave form is shown in Figure 3.

If the violin string could be bowed uniformly and in a manner that would keep the string vibrating continuously at a constant amplitude the resulting wave would be continuous thus producing a steady sound. Such a continuous wave form is also shown in Figure 3 and represents a graphic picture of the continuous radio wave.

Undamped (continuous) oscillations of very high frequency must be employed in broadcast transmission. The frequency of this current is too high to be audible. The wave produced by such rapid electrical vibrations serves no purpose in this form, first, because the diaphragm of the telephone receiver or loudspeaker could not follow such a rapid reversal of current and, second, even if the telephone diaphragm could follow such rapid vibrations the ear would not respond to the vibrations produced.

It will be remembered from the lesson on sound that the wire telephone transmitter is employed to modulate, that is, change the current flowing through the transmitter. This was accomplished by the sound waves causing the diaphragm of the transmitter to vibrate at the frequency of these sound waves, thus compelling the carbon granules to vary their pressure. This change in their pressure varies their resistance causing the current to vary in accordance with the vibrations of the diaphragm.

In Radio telephony the high frequency and inaudible electrical oscillations are modulated by the use of a telephone transmitter (the microphone) which gives them the same wave form as that of the sound wave coming from speech or music. The inaudible, high frequency oscillating current, called the carrier current, cannot be heard in the receiver, but the changes in this current produced by the action of the modulator (when correct adjustments are maintained in the modulator circuit) will follow the wave forms of sounds produced before the microphone, and these are heard in the receiver.

Figure 4, consisting of an antenna, an inductance "L" for tuning the antenna, the high frequency alternator, and a microphone, shows a very simple means for illustrating the generation and modulation of undamped continuous high frequency oscillations. When no sound waves strike the microphone rapid high frequency currents as shown in Figure 5 are continuously and uniformly supplied to the transmitting antenna.

Sound waves, impinging upon the diaphragm of the microphone, will by inward and outward displacements of the diaphragm vary the resistance

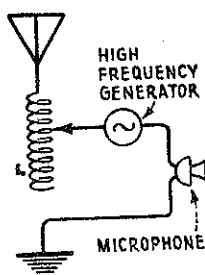


Figure 4

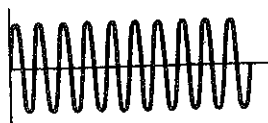


Figure 5

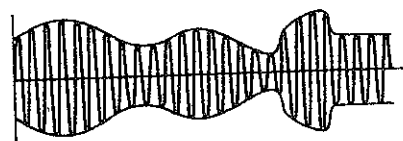


Figure 6

of the carbon granules through which the high frequency current is passing. By virtue of this varying resistance the antenna current will also be varied resulting in a change in amplitude of the antenna current. These changes will produce a wave having the same form as the sound waves being produced before the microphone. Figure 6 shows a modulated carrier wave.

When these electromagnetic waves pass a receiving antenna they will produce therein a feeble electric current which, when conducted to a receiver by a proper arrangement of conductors, will be amplified, detected and again amplified, and then passed through a telephone receiver which reconverts the current to sound waves.

Further work on transmitter problems will be taken up in later lessons. With the preceeding introduction we will begin our work with the radio receiver. Before going on, however, let us sum up the work we have covered by referring to Figure 7.

A suitable apparatus for producing undamped continuous high frequency currents shown at B is necessary. This current is passed through the modulating apparatus at C. The transmitting antenna is shown at G.

When no sound vibrations are impinged upon the microphone the high frequency current oscillates continuously and uniformly in the antenna as shown at D. When sound waves, caused by speech or music, are produced at the microphone they create audible electrical frequencies which superimpose the speech and music vibrations on the high frequency, or carrier wave D. In combining the voice and music waves with the carrier wave at the modulator system the high frequency carrier wave is changed in form, and the contour of a line drawn through the tops of the wave will be seen to correspond exactly to the speech and music sound waves at the microphone, shown at F. The powerful carrier wave is, in this form, projected from the transmitting antenna G, and travels away through space in all directions. Passing through space the carrier, in electromagnetic form, is picked up by a receiving antenna H and still maintains the same frequency and shape as it had on leaving the transmitting antenna but in greatly attenuated form, that is, greatly reduced in strength as shown at I. By means of a lead-in wire from the antenna the electro-

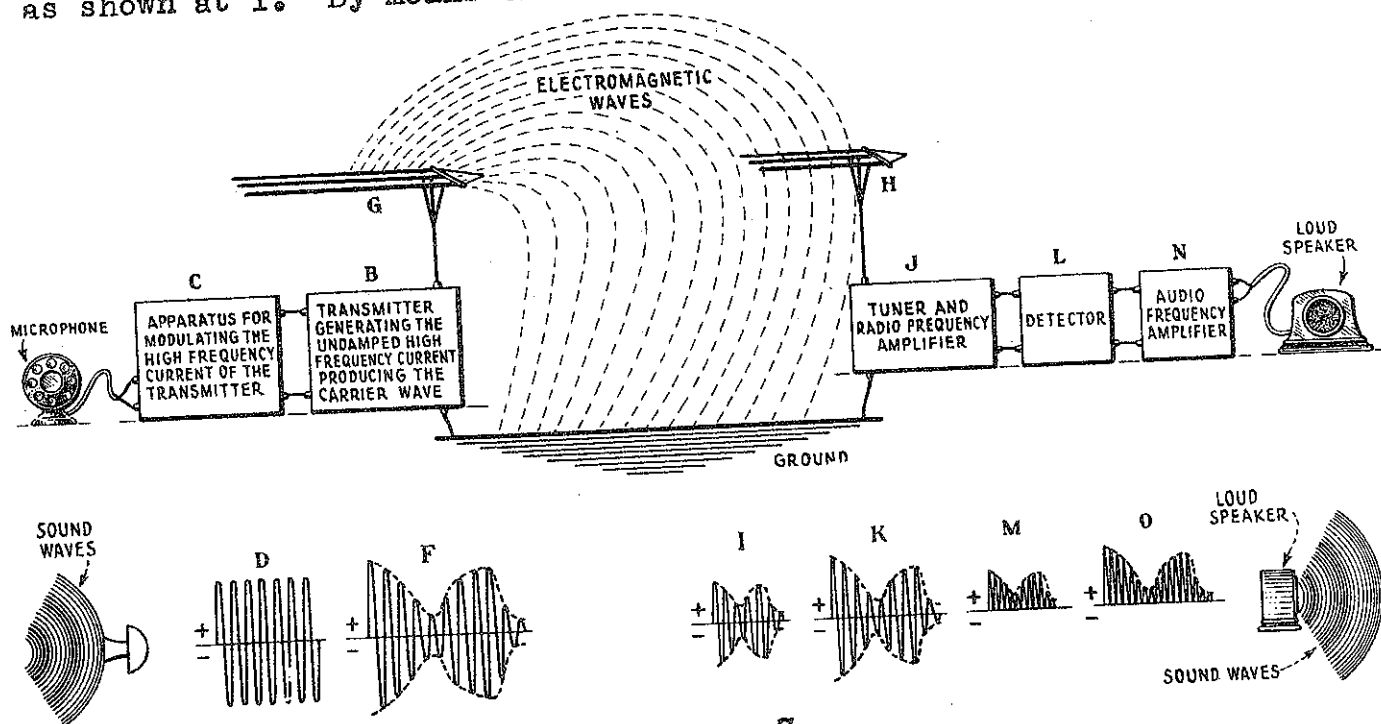


Figure 7

magnetic wave is guided to that part of the receiver called the tuner or selector, J, which is controlled manually by the operator, and which functions in such a manner as to permit the selection of one particular frequency and the exclusion of others. This is called "tuning" and, in tuning, the operator is enabled to select the station he desires.

When the selector of the receiver has been tuned to the proper frequency the modulated carrier I is passed through a radio frequency amplifier which greatly amplifies, that is, magnifies the feeble received current to a strength which will satisfactorily operate the detector L. The detector L transforms or rectifies the high frequency inaudible carrier current and allows the audible component, (this audible component being

shown by the shape of the wave, as in Figure 6, which corresponds exactly to the shape of the carrier produced at the transmitter), to pass as shown at M. This transformed current M is now amplified, as shown at O, to the strength suitable to operate a loud speaker. The receiver converts the electromagnetic waves back to sound waves, reproducing the sound produced at the microphone of the broadcasting station.

The explanation of the apparatus necessary for transforming the electromagnetic waves into sound waves will now be given under receiving apparatus.

RECEIVING APPARATUS

Regardless of the type of the radio receiver employed it must consist of the following parts. The antenna system, tuner, detector, and telephone headset or loud speaker.

THE ANTENNA

The antenna system is necessary to intercept the transmitted electromagnetic waves. It may be a single wire strung between two poles, between the side of a building and pole, or it may be located inside the house, as, for example, in the attic or around the mouldings of the room. Another form of antenna is the loop antenna which is used in locations where other forms of antennae are impracticable, or with a receiving set primarily designed to operate with this type of antenna.

The antenna, also called the aerial, is a system of conductors designed for radiating or absorbing electromagnetic waves. An antenna designed for radiating electromagnetic waves is employed at the transmitting station. The antenna designed for absorbing electromagnetic waves is employed at the receiver.

There are several forms of receiving antennae found in general use. They are the so called L and T type, the inside type, and the loop antenna. In general only a single wire antenna is used for broadcast reception. It is more efficient than an elaborate system comprising several wires. The L type antenna consists of a horizontal wire having a vertical lead-in which is attached to the horizontal part of the antenna nearest the receiving set. This form of antenna is easily installed wherever the wire can be run from one building to another, as from the house to the garage.

The T form of antenna consists of a horizontal wire like the L type, but instead of the lead-in being taken from the end, it is connected to the center of the horizontal wire. This form is generally employed when the lead-in can be dropped directly to the receiver. The L and T antennae are outdoor types and they are usually the most satisfactory.

They should range in length from 65 to 150 feet, and be elevated at least 30 feet from the ground. No. 14 seven strand copper wire, or

No. 12 hard drawn copper, should be used in the construction of the antenna. In sections where excessive smoke, acid or other fumes are prevalent, the enameled form of antenna wire is best. The enamel serves as a protection from the corrosive effects of the smoke and fumes.

With the single wire antenna two strain insulators are placed at each end of the antenna wire and serve to insulate the antenna from the supports to which it is fastened. The insulator is necessary to prevent leakage of the electromagnetic energy which has been "picked up" by the antenna. Insulators for this purpose are made of substances which are non-conductors of electricity. Pyrex glass, glazed porcelain, and special impregnated compositions are used as insulators.

When the antenna is to be run along the side of a building "stand off" insulators should be used to hold the lead-in at least 4 or 5 inches away from the side of building.

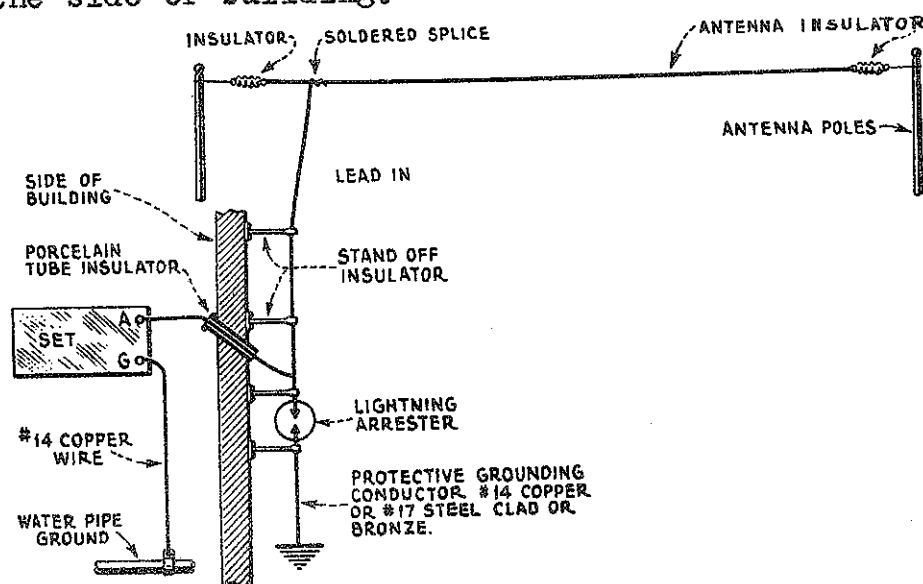


Figure 8

A porcelain tube insulator is employed for leading the wire into the building. The tube will vary from 8 to 16 inches in length, depending upon the thickness of the wall.

The window strip lead-in is used where it is undesirable to drill an opening in the wall of a building for the porcelain tube type of lead-in insulator.

A lightning arrester of a type approved by the Fire Underwriters is necessary to complete the antenna installation.

INSTALLATION

Figure 8 is a diagram showing the installation of an L type single wire antenna. Whenever possible plan the installation so that the

horizontal part of the antenna will be from 65 to 100 or 150 feet in length. At least 30 feet should separate the horizontal part of the antenna and ground. Should it be necessary to install the antenna on the top of a building, a clearance of twelve to fifteen feet is allowed between the horizontal wire and the roof.

Figure 8 shows the lead-in soldered to the horizontal part of the antenna. If possible run the horizontal part from the far insulator through the insulator at the receiver end, through the stand off insulators to the lightning arrester, using a continuous length of wire as shown in Figure 9, thereby avoiding soldered joints.

From the antenna side of the lightning arrester the lead-in is continued through the porcelain tube. When the porcelain tube lead-in insulator is used a hole is bored in the window casing at an angle as shown in Figure 8. There are various kinds of lead-in devices, - some are flat copper ribbon covered with an insulating fabric, called window strips. Such a device is laid over the window sill and the window closed tightly on it. Other methods may be used, as, for example, using a board about two inches in width and the length of the window, inserting the porcelain insulator through the board and then closing the window on it as shown

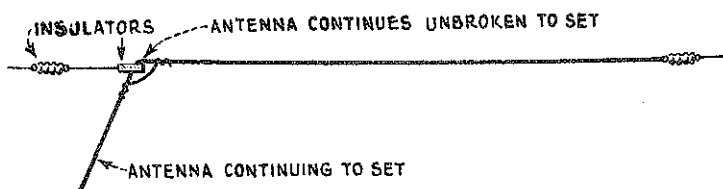


Figure 9

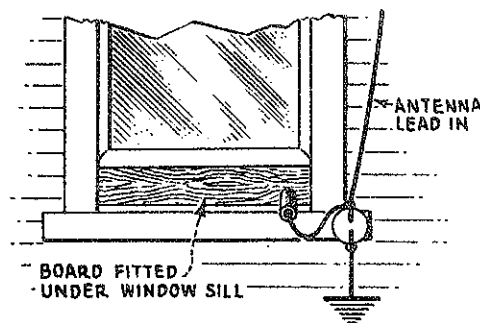


Figure 10

in Figure 10. This part of the installation will have to be governed by the wishes of the owner of the house. The lead-in is then connected to the binding post of the receiver marked A, or antenna. From the binding post on the receiver marked G, or ground, a wire is connected direct to the ground. This should be No. 14 B & S gauge rubber covered insulated wire. A smaller wire may be used from receiver to ground provided a No. 14 wire is connected from lightning arrester to ground.

THE LIGHTNING ARRESTER

The lightning arrester is a device employed in the antenna installation to protect the receiving set from heavy electrical charges absorbed by the antenna. An antenna does not attract lightning to a greater extent than electric light and telephone lines. It should be understood that, if lightning directly strikes an antenna, electric light, or telephone wire, no arrester will offer absolute protection.

When an atmospheric storm is in progress, however, there is always an electrical charge accumulating on the antenna. It is this charge which,

on becoming sufficiently strong, is carried harmlessly to ground by the arrester and the protective grounding conductor. These undesirable charges do not pass through the various parts of the receiver. All antenna systems should be equipped with some form of approved lightning arrester.

The lightning arrester consists of two electrodes securely supported and separated from each other by an air gap, as shown in Figure 11. The spacing of this air gap is such that excessive charges accumulating on the antenna will jump the gap and pass directly to ground, thus preventing a heavy charge from passing through the receiving parts.

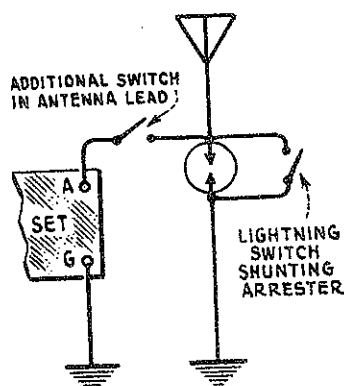


Figure 11

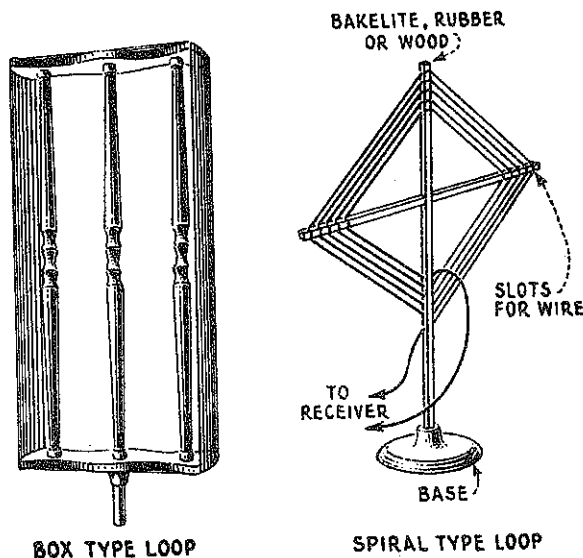


Figure 12

INDOOR ANTENNAE

The indoor antenna should be insulated wire unless the supports on which the wire is run are, in themselves, insulators. The same rules and precautions should be exercised in indoor installations as in outdoor, - the more careful the installation the better the results obtained.

A single straight wire may be installed in a long attic in the same general manner as the outdoor aerial. Some buildings are small, however, and it may be necessary to loop the wire back and forth on porcelain cleats or knob insulators. In some cases the wire is supported along the top of the picture moulding about the room. The wire in this case should be insulated, but cleats are unnecessary.

Any of these indoor antenna will function but they will not deliver as strong an impulse to the receiver as the outdoor type and, when installed in steel frame buildings, the decrease in signal strength may be quite marked.

LOOP ANTENNAE

Under certain conditions the coil, or loop, antenna will give very good results. The loop antenna consists of a number of turns of wire wound on a wooden frame varying in size from ten inches to five feet square. Some loops are oblong in shape. Figure 12 shows two forms of loops.

The loop, because of its size, cannot be used for distant reception unless suitable apparatus is used to greatly amplify the minute energy absorbed by the loop. (The "super-heterodyne" receiver operates most satisfactorily with a loop aerial.) There are several good features in using the loop antenna when the proper amplification is available. First, it is directional, that is, when the loop is turned so that one edge is pointing in the direction of the transmitting station signals from that station will be absorbed by the loop at maximum intensity; turning it away from this position the signals become weaker and, when it is at right angles to the transmitting station, no signal will be received. When the loop is pointed toward any particular station it tends to exclude stations that may be located on either side, with the exception of nearby powerful transmitters.

While the energy received by a loop antenna is quite small the amount received can usually be amplified to sufficient intensity to give loud and clear signals.

UNDERGROUND ANTENNAE

Electromagnetic waves penetrate the surface of the earth to a short depth with fair signal strength. This is taken advantage of in the underground antenna system due to the better signal to static ratio; it is more selective than the overhead form and its directional effect is very pronounced.

This type of antenna should be made of No. 14 hard drawn copper wire at least 75 feet in length and insulated by a quarter inch thickness of good rubber insulation. It should be buried to a depth of from 8 inches to two feet, preferably in moist ground.

The signal strength received by the underground aerial is very small and suitable amplification is required to satisfactorily operate a loud speaker.

CONNECTING THE LOOP

When the loop antenna is employed the ends of the loop are connected to the antenna and ground binding posts of the set respectively if the tuner has a coil and condenser in series.

When the tuner consists of a coil only, then a condenser must be connected in series with one side of the loop and the ground connection of the set. In some sets the loop is used in place of the tuning coil and when this is done a condenser must be placed across the loop terminals to tune the loop. Loop connections are shown in Figure 13.

MULTIPLE WIRE ANTENNAE

Difficulty is experienced, at times, in running a single straight wire for the antenna due to lack of space. In that case the multiple wire antenna may be resorted to.

Figure 14 shows two forms, - a two wire L antenna and a three wire T type antenna. The parallel horizontal wires should be spaced at least 2 feet. The signal strength with the two wire form will be slightly increased as compared with the strength received by the single wire, and the signal strength of the three wire form will be about one and a half times as great as the single wire.

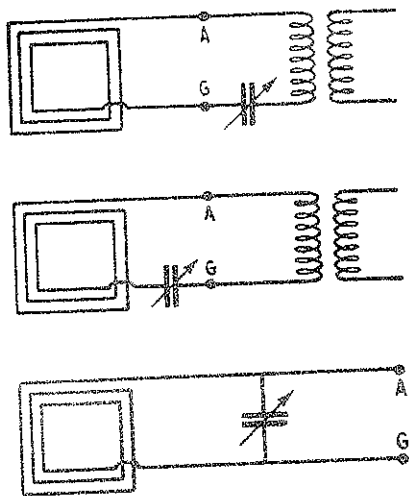


Figure 13

The wires in a multiple antenna should be exactly the same length and should be separated by wood spreaders. Each wire can be run through a hole bored in the spreader, taking a turn or two and then brought out and twisted back on the horizontal section of the antenna; or they may be secured with insulators as shown in the three wire form.

Insulators should always be placed between the supports and the antenna proper in all types of antennae to prevent electro-magnetic leakage.

THE COUNTERPOISE

The counterpoise is a system of wires erected underneath the antenna. It may be placed a few feet above the ground, from two to 10 feet, and should follow the design, as to length and shape, of the horizontal part of the antenna. It is still better, however, to have it cover a greater space than that covered by the antenna proper.

If the antenna is erected on the top of a building the counterpoise may be located in the attic under the antenna, or in the cellar, providing the roof is not a metal one, otherwise it is better to place it directly under the antenna above the roof. The counterpoise, when

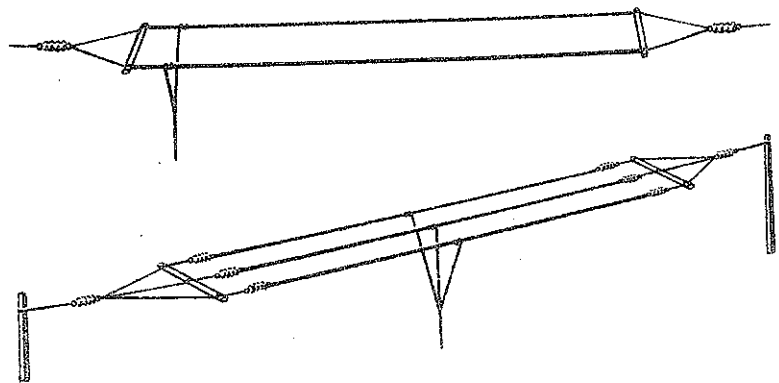


Figure 14

employed, takes the place of the ground, and in locations where the earth is very dry it will give better results than the ground. The same rules in installation apply as those followed in erecting an antenna.

RIGHT AND WRONG ROOF INSTALLATIONS

The two illustrations in Figure 15 show the correct and incorrect methods of erecting supports for antennae on roof tops.

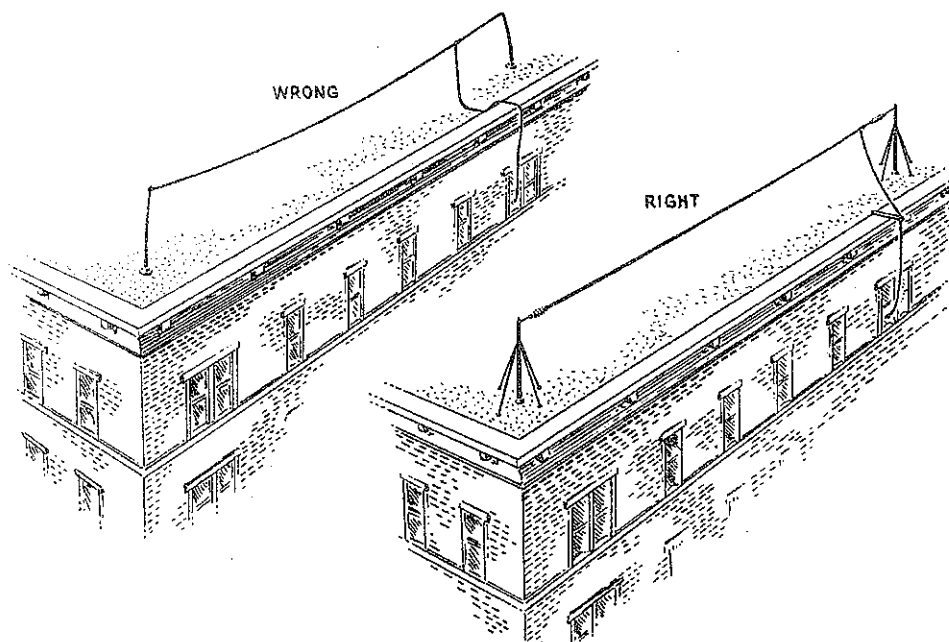


Figure 15

FIRE UNDERWRITERS REGULATIONS

General

The requirements of this article shall not apply to equipment installed on shipboard, but shall be deemed to be additional to, or amendatory of, those prescribed in articles 1 to 19, inclusive, of this code.

Transformers, voltage reducers, keys and other devices employed shall be of types expressly approved for radio operation.

For Receiving Stations Only.

a. Antenna and counterpoise outside buildings shall be kept well away from all electric light or power wires of any circuit of more than 600 volts, and from railway, trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions.

b. Antenna and counterpoise, where placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be so located and provided with suitable clearance as to prevent accidental contact with such wires by sagging or swinging.

c. Splices and joints in the antenna span shall be soldered unless made with approved splicing devices.

d. The preceding paragraphs, a, b, and c, shall not apply to light and power circuits used as receiving antenna, but the devices used to connect the light and power wires to radio receiving sets shall be of approved type.

e. Lead-in conductors shall be of copper, approved copper-clad steel or other metal which will not corrode excessively, and in no case shall they be smaller than No. 14, except that bronze or copper-clad steel not less than No. 17 may be used.

f. Lead-in conductors on the outside of buildings shall not come nearer than 4 inches to electric light and power wires unless separated therefrom by a continuous and firmly fixed non-conductor which will maintain permanent separation. The non-conductor shall be in addition to any insulating covering on the wire.

g. Each lead-in conductor shall enter the building through a non-combustible, non-absorptive, insulating bushing slanting upward toward the inside or by means of an approved device designed to give equivalent protection.

h. Each lead-in conductor shall be provided with an approved protective device (lightning arrester) which will operate at a voltage of 500 volts or less, properly connected and located either inside the building at some point between the entrance and the set which is convenient to a ground, or outside the building as near as practicable to the point of entrance. The protector shall not be placed in the immediate vicinity of easily ignitable stuff, or where exposed to inflammable gases or dust or flyings of combustible materials.

i. If an antenna grounding switch is employed, it shall, in its closed position, form a shunt around the protective device. Such a switch shall not be used as a substitute for the protective device.

It is recommended that the antenna grounding switch be employed, and that in addition a switch rated at not less than 30 amperes, 250 volts, be located between the lead-in conductor and the receiver set.

j. If fuses are used, they shall not be placed in the circuit from the antenna through the protective device to ground.

k. The protective grounding conductor may be bare and shall be of copper, bronze or approved copper-clad steel. The protective grounding conductor shall not be smaller nor have less conductance per unit of length, than the lead-in conductor and in no case shall be smaller than No. 14 if copper, nor smaller than No. 17 if of bronze or copper-clad steel. The protective grounding conductor shall be run in as straight a line as possible from the protective device to a good permanent ground. Preference shall be given to water piping. Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building, and artificial grounds such as driven pipes, rods, plates, cones, etc. Gas piping shall not be used for the ground.

L. The protective grounding conductor shall be guarded where exposed to mechanical injury. An approved ground clamp shall be used where the protective grounding conductor is connected to pipes or piping.

m. The protective grounding conductor may be run either inside or outside the building. The protective grounding conductor and ground, installed as prescribed in the preceding paragraphs K and L, may be used as the operating ground.

It is recommended that in this case the operating grounding conductor be connected to the terminal of the protective device.

If desired, a separate operating grounding connection and ground may be used, this operating grounding conductor being either bare or provided with an insulated covering.

n. Wires inside buildings shall be securely fastened in a workmanlike manner and shall not come nearer than 2 inches to any electric light or power wire not in conduit unless separated therefrom by some continuous and firmly fixed non-conductor, such as porcelain tubes or approved flexible tubing, making a permanent separation. This non-conductor shall be in addition to any regular insulating covering on the wire.

o. Storage battery leads shall consist of conductors having approved rubber insulation. The circuits from storage batteries shall be properly protected by fuses or circuit breakers rated at not more than 15 amperes and located preferably at or near the battery.

For Transmitting Stations Only.

a. Antenna and counterpoise outside buildings shall be kept well away from all electric light or power wires of any circuit of more than 600 volts, and from railway, trolley, or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions.

- b. Antenna and counterpoise, where placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be so located and provided with suitable clearances as to prevent accidental contact with such wires by sagging or swinging.
- c. Splices and joints in the antenna and counterpoise span shall be soldered unless made with approved splicing devices.
- d. Lead-in conductors shall be of copper, bronze, approved copper-clad steel or other metal which will not corrode excessively and in no case shall be smaller than No. 14.
- e. Antenna and counterpoise conductors and wires leading therefrom to ground switch, where attached to buildings, shall be firmly mounted 5 inches clear of the surface of the building, on non-absorptive insulating supports such as treated pins or brackets, equipped with insulators having not less than 5 inches creepage and air-gap distance to inflammable or conducting material, except that the creepage and air-gap distance for continuous wave sets of 1000 watts and less input to the transmitter, shall be not less than 3 inches.
- f. In passing the antenna or counterpoise lead-in into the building a tube or bushing of non-absorptive, insulating material, slanting upward toward the inside, shall be used and shall be so insulated as to have a creepage and air-gap distance of at least 5 inches to any extraneous body, except that the creepage and air-gap distance for continuous wave sets of 1000 watts and less input to the transmitter, shall be not less than 3 inches. If porcelain or other fragile material is used it shall be protected where exposed to mechanical injury. A drilled window pane may be used in place of a bushing provided creepage and air-gap distance as specified above is maintained.
- g. A double-throw knife switch having a break distance of at least 4 inches and a blade not less than $1/8$ inch by $1/2$ shall be used to join the antenna and counterpoise lead-in to the grounding conductor. The switch may be located inside or outside the building. The base of the switch shall be of non-absorptive insulating material. This switch shall be so mounted that its current-carrying parts will be at least 5 inches clear of the building wall or other conductors, except that for continuous wave sets of 1000 watts and less input to the transmitter, the clearance shall be not less than 3 inches. The conductor from grounding switch to ground shall be securely supported.

It is recommended that the switch be located in the most direct line between the lead-in conductors and the point where grounding connection is made.

- h. Antenna and counterpoise conductors shall be effectively and permanently grounded at all times when station is not in actual

operation and unattended, at a conductor at least as large as the lead-in and in no case smaller than No. 14 copper, bronze, or approved copper-clad steel. This protective grounding conductor need not have an insulated covering or be mounted on insulating supports. The protective grounding conductor shall be run in as straight a line as possible to a good permanent ground,- preference shall be given to water piping. Other permissible protective grounds are the grounded steel frames of buildings and other grounded metal work in buildings and artificial grounding devices such as driven pipes, rods, plates, cones, etc. The protective grounding conductor shall be protected where exposed to mechanical injury. A suitable approved ground clamp shall be used where the protective grounding conductor is connected to pipes or piping. Gas piping shall not be used for the ground.

It is recommended that the protective grounding conductor be run outside the building.

i. The operating grounding conductor shall be of copper strip not less than $\frac{3}{8}$ inch wide by $\frac{1}{32}$ inch thick, or of copper, bronze, or approved copper-clad steel having a periphery, or girth, of at least $\frac{3}{4}$ inch, such as No. 2 wire, and shall be firmly secured in place throughout its length.

j. The operating grounding conductor shall be connected to a good permanent ground. Preference shall be given to water piping. Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building, and artificial grounding devices such as driven pipes, rods, plates, cones, etc. Gas piping shall not be used for the ground.

k. Where the current supply is obtained directly from lighting or power circuits, the conductors whether or not lead covered shall be installed in approved metal conduit, armored cable or metal raceways.

L. When necessary to protect the supply system from high-potential surges and kick-backs there shall be installed in the supply line as near as possible to each radio transformer, rotary spark gap, motor and generator in motor generator sets and other auxiliary apparatus one of the following:

1. Two condensers (each of not less than $\frac{1}{10}$ microfarad capacity and capable of withstanding 600 volt test) in series across the line with mid-point between condensers grounded; across (in parallel with) each of these condensers shall be connected a shunting fixed spark-gap capable of not more than $\frac{1}{32}$ inch separation.

2. Two vacuum tube type protectors in series across the line with the mid-point grounded.

3. Resistors having practically zero inductance connected across the line with mid-point grounded.

It is recommended that this third method be not employed where there is a circulation of power current between the mid-point of the resistors and the protective ground of the power circuit.

4. Lightning arresters such as the aluminum cell type.

ANTENNA TROUBLES

Too great haste in the construction of the antenna will, in time, usually cause trouble.

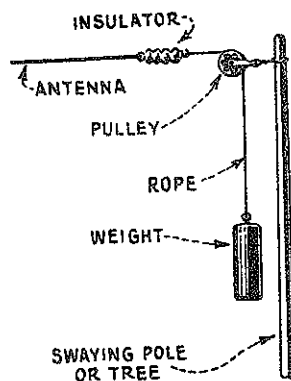


Figure 16

The antenna should be inspected periodically for grounds, broken, cracked, and corroded insulators, weak supports, etc. On such an inspection the antenna will often be found to be making contact with parts of the roof, the lead-in in contact with metal gutters, conduit pipes, or the side of the building. Where a tree supports one end of the aerial it may be found that it is coming in contact with the branches. The remedy in such cases is obvious. If the antenna has stretched it should be tightened up, broken and cracked insulators should be replaced. Where the antenna or lead-in is found to be making contact with any part of the building measures should be adopted to prevent a recurrence of such contact. Branches of trees or the damp side of a frame building will form an excellent path to ground.

A defective lightning arrester will ground the antenna resulting in weak signal strength. The remedy is to replace it with a new arrester.

When one end of the antenna is attached to a tree or pole that sways with the wind, precautions should be taken to prevent the antenna from breaking by excessive strain. Swaying anchorages are not desirable but are sometimes necessary. Figure 16 is a suggested method which has

been used to prevent the antenna from breaking due to excessive swaying of supports.

EXAMINATION - LESSON 21

1. The frequency of a certain station is 1,250,000 cycles. What is it's frequency in kilocycles?
2. What is the wave length when the frequency is 566,000 cycles?
3. What is a continuous wave?
4. Of what particular use or uses is the antenna?
5. What is the velocity (approximately) of a radio wave expressed in terms of meters?
6. What precautions should be taken when installing antennae?
7. What is a lightning arrester?
8. What is the protective grounding conductor? What size of wire should be used for this purpose?
9. Is grounding on a gas pipe permissible?
10. What are some of the types of antennae employed for receiving purposes? Make diagrams of at least three types.